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Fertilizing Agricultural Land with Rainbow Trout Manure for Growing Silage Corn[1]

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ABSTRACT

Field plots on a Portneuf silt loam (mesic, Durixerollic Calciothids) were fertilized with fish manure at 0, 200, 500, or 800 kg N/ha or NH_4NO_3 at 0, 100, 200, and 300 kg N/ha for one, two, or three years and planted to corn (*Zea mays* L.) for four consecutive years. Corn silage yields up to 24 Mg/ha (dry weight) were obtained the first season in 1979 with no significant differences because of the high residual fertility. Highly significant yield increases were obtained the second, third, and fourth season from manure or NH_4NO_3. The yields were somewhat lower than those obtained the first season. In four years of cropping to corn with manure applied for the first three crops, N recovery for the manure treatments was 18, 28, and 24% of applied manure N for the 200, 500, and 800 kg N/ha applications for three years. In comparison treatments using NH_4NO_3, N recovery was 90, 59, and 57% for the 100, 200, and 300 kg N/ha treatments. The manure applications at 500 kg N/ha provided enough N for high corn silage yields and were about equal to the yields obtained with 200 kg N/ha as NH_4NO_3. Residual N fertility from the manure was greater than from NH_4NO_3.

Additional Index Words: **corn silage, manure decomposition, N recovery.**

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IDAHO is the leading producer of commercial Rainbow Trout (*Salmo gairdneri* L.) in the USA. The sale of Idaho food-size trout for 1 Jan. to 21 July 1980 was 11 300 Mg according to the Idaho Crop and Livestock Reporting Service (1980). Waste disposal from this industry has become a problem with enforcement of the Clean Water Act amendments of 1972, which prohibits the trout producers from discharging fish manure wastes into the streams. Currently the trout rearing raceways are frequently cleaned by pumping the solid wastes from the raceway bottom to a retaining pond. When the pond is full of the settled solids, the manure is removed, partially dried, and spread on agricultural land. The annual trout manure production for Idaho is about 13 000 Mg. About 0.67 kg of waste is produced for each kg of marketable fish (Smith, et al., 1980) Of this waste, approximately half is solid and half is liquid. Much of the N is lost into the raceway water as ammonia excreted from the fish gills.

Little information is available about utilization of fish manure. Fish wastes used for feed and fertilizer are primarily from the fish and seafood processing industry (Aung, L. H., et al. 1981; Swanson, G.R., et al., 1980). The objectives of this research project were to determine the N content and availability of rainbow trout manure and to compare the manure with NH_4NO_3 for fertilizing corn (*Zea mays* L.).

MATERIALS AND METHODS

A field experiment was established in 1979 at Kimberly, Idaho on Portneuf silt loam soil (course-silty, mixed, mesic, Durixerollic Calciothids). Treatments included rainbow trout manure at rates of 0, 200, 500, or 800 kg N/ha and NH_4NO_3 was applied at 0, 125, 250, or 375 kg N/ha in 1979 and 0, 100, 200, or 300 kg N/ha in 1980 and 1981. The manure was analyzed for total Kjeldahl N each year and appropriate amounts applied. The manure was sampled moist as it was obtained from the fish farm, analyzed for total Kjeldahl nitrogen (TKN) and reported on a moist basis later. The different rates for N application in the manure and NH_4NO_3 treatments were established because the fish manure decomposes and releases N slower than commercial fertilizer. A randomized complete block design with three replications was split by years including check plots to evaluate cropping year and residual fertility from fish manure and NH_4NO_3 fertilizer. The main plots were 14.6 m long by 14 m wide. There were 18 rows per plot with row spacing of 76 cm. In 1979, the main plots were treated with manure or NH_4NO_3. In 1980, 12 rows were treated again as in 1979 and six rows were left untreated for residual evaluation. In 1981, six rows were treated as before, six rows were left for 1 yr, and 6 rows for 2-yr residual evaluation. In 1982 no fertilizer or manure was applied.

Immediately after the fertilizers were applied, the plot area was rototilled about 15 cm deep, roller harrowed for seedbed firming, treated with recommended rates of "Eradicane" (EPTC) plus seed protectant for weed control, disced, smoothed, and seeded. The plots were seeded on 17 May 1979, 21 May 1980, 18 May 1981, and 17 May 1982 with 'Northrup King PX606' three-way cross hybrid seed corn spaced 14 cm in rows for 94 000 plants/ha. The field was furrow irrigated from the irrigation canal as needed for optimum growth. Harvesting was done on 1 Oct. in both 1979 and 1980, on 28 Sept. 1981, and on 30 Sept. 1982. At harvest, two 3 m rows of corn were cut by hand from the center of each plot, weighed, run through a forage chopper, mixed, sampled moist, weighed, and dried for moisture and chemical analyses. The plant samples were analyzed for TKN (American Public Health Association, Inc., 1971). The data were analyzed by analyses of variance, LSD, and CV calculated according to LeClerg (1957).

The fish manure was collected in ponds dug in the soil. Composition of the excavated manure is somewhat dependent on the amount of soil mixed with the manure during excavation. The total N content of the manure varied with years because of the soil mixing. As it was applied to the experimental plot areas, the moist manure contained 13.8 g Kg^{-1} in 1979, 7.9 g Kg^{-1} in 1980 and 4.5 g Kg^{-1} in 1981. The manure used in 1981 was removed from a relatively new pond and contained an unusually large amount of soil. Manure N is also decreased by leaching in the raceway, and by denitrification in the impoundment. Fresh fish manure from the raceway is much higher in N than the manure used

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in these experiments. The manure contains other nutrients such as P and K as well as trace elements (Kreiger, et al., 1985). The fertility rates will be referred to as 200*M*, 500*M*, and 800*M* for the manure treatments and as 100*N*, and 200*N*, and 300*N* for the NH_4NO_3 treatments. The nitrate soil test was 60 g Kg^{-1} N in the surface 30 cm before treatments were imposed. Soil levels of P and K were high, thereby eliminating response to these elements.

RESULTS AND DISCUSSION

Corn silage yields on a dry weight basis for four years of cropping are given in Fig. 1. The general fertility level in the plot area was high when the treatments were imposed and decreased in the check plots with cropping to corn. This is reflected by yield decreases from 20 to 10 Mg/ha on the check plots from 1979 to 1981 with no further decrease for 1982. The 100*N* and 200*M* fertilizer treatments followed yield decrease trends but to a lesser extent than the check. After 1979, highly significant differences were observed between yields with NH_4NO_3 or manure N and check treatments (Fig. 1, Table 1). For these treatment rates, the annually fertilized plots yielded more silage than those fertilized either two or one years. The 200*N* plots that were annually fertilized produced about 20 MG/ha silage in 1979 and 17 Mg/ha in each year 1980 and 1981. In 1982, following annual fertilizing, but with no N applied in 1982, the 200*N* plots yielded about 14 Mg silage/ha. Nitrogen applications at the 200 kg/ha rate produced higher silage yields than check plots in 1980 and 1981. Corn silage yields from the 300*N* plots were similar to those on the 200*N* plots except for a greater yield in the residual year (1982). In 1982, the 300*N* annually fertilized plots showed a better yield trend than the 200*N* annually fertilized plots while yields from only the annually fertilized plots exceeded check plot yields due to residual fertility. In all cases, corn silage yields in 1980, 1981, and 1982 were less than those obtained in 1979. Whether this yield decline developed due to seasonal variation or other factors was not determined.

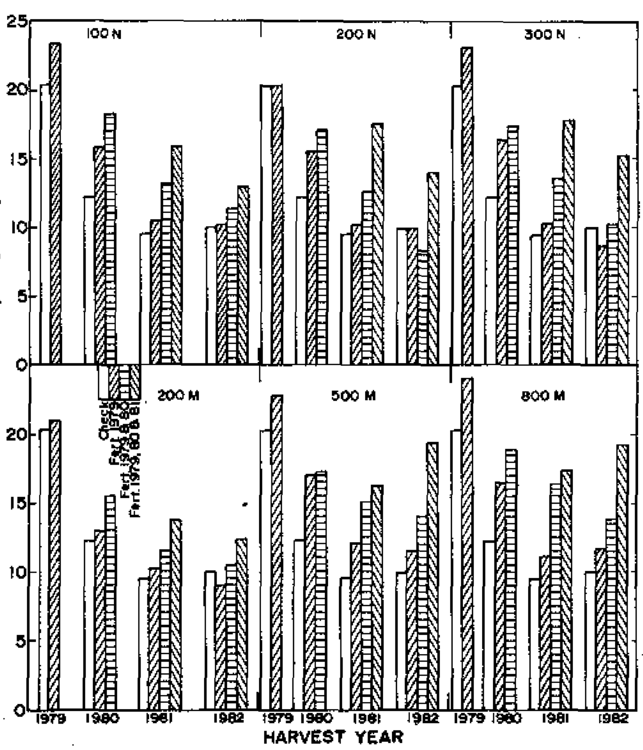

Fig. 1.—Corn silage yield from plots fertilized with Rainbow trout manure or NH_4NO_3 fertilizer.

In the 500*M* plots, the silage yields remained at the level near 17 Mg/ha in 1980, 1981, and in the residual year. Corn silage yields for plots fertilized with fish manure for only one or two years declined in residual years. In all cases at the 500*M* and 800*M* rates, the manure-fertilized plots yielded significantly more corn silage than the check plots (Table 1). The 500*M* and 800*M* treatments produced virtually identical yields in all years, including the residual year (Fig. 1).

Accumulative Fertilization Effects

There was an upward trend in N-uptake with fertilization in 1979 (significant at 80% probability). Residual fertility in the plots, the general variability, and few degrees of freedom in the analysis prevented a higher level of significance. In later years, as cropping decreased residual fertility in the check plots, and as the addition of treatments by splitting plots increased statistical precision, treatment differences were highly significant (Table 1). In 1980, N uptake was significantly increased with each manure application in 1979 and 1980. Nitrogen uptake from the NH_4NO_3 treatments increased in much the same manner as from the manure treatments, but no differences were observed in N uptake between the 200*N* and 300*N* treatments for 1980. Corn receiving N took up more than did corn utilizing residual N. In 1981, N uptake increased with increasing fertilization to almost the same extent as in 1980. In the 1982 cropping year, the influence on N uptake of N applied in 1979 with either manure or NH_4NO_3 was almost entirely gone. Residual N from fertilization in 1979 and 1980 was still detected in the manure treatments but not in the NH_4NO_3 treatments. There was a significant carryover of N on treatments that were fertilized with manure or NH_4NO_3 for three years (1979, 1980, and 1981) (Table 2).

The 200M treatment was too low and did not consistently increase corn yield or N uptake relative to the controls. Nitrogen uptake increased with rate, but N utilization efficiency did not necessarily increase. In the residual treatments, N uptake from manure was

Table 1. Significance levels for corn silage yields reported in Fig. 1 and nitrogen uptake in Table 2.

Factors	1979	1980	1981	1982
		Corn silage yield		
Nitrogen	NS	0.001	0.001	0.001
Years fertilized	--	0.001	0.001	0.001
N × yr	--	NS	0.05	0.01
LSD (0.05)	--	2.3	2.7	2.8
CV, %	15.2	8.5	12.5	14.1
		Nitrogen uptake		
Nitrogen	0.20	0.001	0.001	0.001
Years fertilized	--	0.001	0.001	0.001
N × yr	--	NS	0.01	0.01
LSD (0.05)	--	37	41	33
CV, %	22.5	15.1	18.3	21.3

Table 2. Nitrogen uptake by silage corn from fish manure or NH_4NO_3 fertilized plots.

	Plots fertilized, years								
	1979	1979	79–80	1979	79–80	79–80–81	1979	79–80	79–80–81
	Harvest years								
Treatment	1979	1980		1981			1982		
	nitrogen uptake, kg/ha								
Check	159	86	81	63	61	73	77	64	73
200*M*†	167	94	126	71	86	104	66	77	93
500*M*	215	152	170	99	171	230	85	105	184
800*M*	234	160	218	80	205	304	93	113	203
100*N*†	232	130	169	76	105	170	73	78	101
200*N*	201	145	184	82	114	269	74	57	110
300*N*	266	158	192	81	128	338	59	74	137
LSD	NS	37	37	41	41	41	33	33	33

† *M* is manure, *N* is NH_4NO_3.

greater than from NH_4NO_3 because more N was applied in manure treatments. After the 1980 cropping year, N uptake on treatments that received either form of N in 1979 only, was not different from the check treatment.

N Utilization or Recovery

In estimating N utilization efficiency by corn it was necessary to make certain assumptions, some of which are subject to error. Lacking absolute values, it was assumed that no loss occurred from leaching, volatilization, or denitrification. These assumptions were based on 90 to 100% recovery of N from the 100N treatment and will be more nearly correct with low than high N applications (Table 3). Nitrogen uptake in corn from each year's check plots was subtracted from N uptake in the corn from treated plots and these values tabulated for each level of fertilization. The net N uptake from either fertilizer source was then calculated as a percentage of the N applied (Table 3). This percentage may also be considered to be equal to the percentage of manure decomposition, as well as the percentage of N recovered from the manure during four cropping seasons.

Decomposition percentages at the highest manure application rates could have been higher than the percentage of N recovered due to some unidentified N losses, but, lacking absolute values, this was the best assumption available and was used as described.

The 500M rate appears to be the best rate because of maximum corn silage yields. However, even at the "best rate" relatively low N recovery was obtained. With a single 500M application and corn grown four years, 34% of the manure N was recovered. With the three manure applications where 1500 kg N/ha was applied, 420 kg N/ha or 28% of the applied N was recovered in the corn silage. At the high manure application rates, after three years manuring, much of the manure probably remained undecomposed in the soil, while some of the manure N may have been lost to leaching, denitrification, or immobilization in soil biomass.

The 800*M* treatments gave lower N recovery percentage than the 500*M* treatments, with 24% N recovery from either one, two, or three years of manure treatments and four cropping years.

Table 3. Nitrogen application, uptake, and recovery with silage corn for cropping years 1979 through 1982 from plots fertilized with rainbow trout manure or NH_4NO_3.

	Plots fertilized, years								
	1979			1979–1980			1979–1980–1981		
Treatment	N applied	N uptake	N recovery	N applied	N uptake	N recovery	N applied	N uptake	N recovery
	kg/ha		%	kg/ha		%	kg/ha		%
Check	0	379	–	0	379	–	0	379	–
200*M*†	200	398	10	400	456	19	600	490	18
500*M*	500	551	34	1000	661	28	1500	799	28
800*M*	800	567	24	1600	770	24	2400	959	24
100*N*†	125	511	106	225	584	91	325	672	90
200*N*	250	502	49	450	556	39	650	764	59
300*N*	375	563	49	675	660	42	975	933	57

† *M* is manure, *N* is NH_4NO_3.

Nitrogen recovery from the NH_4NO_3-fertilized plots ranged from about 100% to 39% of the applied N in four years with the various N application rates (Table 3). The near 100% N recovery with the low N application rate indicates than leaching and denitrification were minor factors in this portion of the experiment, although with high applications of manure there is the possibility for anaerobic conditions developing and some denitrification occurring. This is a factor that was not evaluated in this experiment, although the factors that promote denitrification may readily have been present in the field (Meek, et al., 1974 and Smith et al., 1976).

The relatively low manure decomposition percentage estimates of the rainbow trout manure may raise some questions. The nature of the manure probably accounts for its low decomposition rate. The manure is voided by fish into moving water and is thoroughly leached of soluble components. The manure has the appearance of undigested feed, but after digestion, collection, and drying it was much lower in N than the fish feed. Since fish excrete most of their waste N as urine and as NH_3 through the gills, these soluble components are lost into the raceway water and are not recoverable. Loss of soluble N may in part account for the relatively slow decomposition observed in the manure used in this experimental study.

The fish manure, when applied at fairly high rates to provide the nutrients needed for growing crops, has a relatively long-lasting residual value that can be used for growing crops in succeeding years. The residual value of the manure can be calculated from the data presented here and can be used to calculate manure applications needed to meet desired fertilization levels in future years. According to the method proposed by Pratt, et al. (1973), for the 500*M* treatment applied only in 1979, and evaluated for residual N availability and decomposition, the following applies: in the first year 12% of the 500 kg N was utilized by corn, in the second year 16% of the remaining 441 kg N was utilized, in the third year 10% of the remaining 370 kg N was utilized, and in the fourth year 2% of the remaining 334 kg N was utilized. Assuming uptake equals decomposition, this would produce a decomposition series of 12, 16, 10, 2, indicating those percentages of the residual manure decomposing in the successive years. These values are probably lower than actual manure decomposition in the field, but give a starting point for evaluating fish manure for fertilizing crops. These decomposition values are also lower than those found by Pratt et al. (1973) for other animal manures.

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